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Patent Application

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BACKGROUND OF THE INVENTION

This invention relates to horizontal, vertical or angularly disposed diaphragms which resist structural forces. As herein used, a diaphragm is a large, thin structural element that is loaded in its plane. A diaphragm at its most basic level has three components: a shear resisting element, which consists of one or more structural panels, a frame and a fastening system for connecting the frame to the shear resisting element. The structural panels which make up the shear resisting element are commonly made of 4'x 8' plywood or Oriented Strand Board (OSB) sheets. Vertical diaphragms in a structure are commonly called shearwalls. Specifically, this invention relates to an improved method of constructing diaphragms. The present invention improves on standard construction and fabrication methods to reduce the bending of the fasteners that make the mechanical connection between the structural panels and the perimeter framing members that support the structural panels.

All structures must be designed to resist lateral forces. Structural units designed to resist lateral forces are commonly called lateral force resisting systems. Lateral forces on a building are typically produced by wind loading and seismic forces. Both, but especially seismic forces, cause cyclic loading, that is, the force on the building reverses direction. The extensive damage caused to buildings by the January 1994 earthquake at Northridge, California has demonstrated that lateral force resisting systems must be improved to better resist cyclic (reversed) lateral loading.

In general there are three types of lateral force resisting systems used in framed buildings. The first type, rigid frames, resist lateral forces by bending in the frame members. The second type, trusses or braced frames, resist lateral forces by primarily carrying the resulting tension and compression forces in diagonal members or cross braces. The third type, shearwalls or diaphragms, are large, flat structural units that act like deep, thin beams with the structural panel or panels of the diaphragms acting as the "web" of the beam and the chords of the diaphragms acting like the "flanges" of the beam. It is thought that shear deformation is the significant action in diaphragms.

The present invention provides an improved method of constructing shearwalls and horizontal diaphragms to serve as improved lateral force resisting systems.

1 When considered in its function of resisting lateral forces, a typical shearwall or diaphragm consists of three structural elements: a frame, a shear resisting element, and a fastening system for attaching the shear resisting element to the frame.

5 The diaphragm, in turn, is integrated into the structure via a connection system. The connection system must be designed to transfer the lateral forces imposed on the building into the diaphragm. In the case of shearwalls or vertical diaphragms, special anchors or transfer members for resisting the moment forces imposed on the shearwall may also be required.

10 In a shearwall, these special anchors typically consist of anchor bolts and holdowns, connecting the bottom of the chords to a structural member below the shearwall. These anchors resist tension forces acting to overturn the shearwall. A holdown is typically attached to the inner face of each chord with heavy screws, nails or bolts. The holdown receives a bolt which
15 is connected to an anchoring structural member below.

Diaphragms and shearwalls are connected to the other structures of the building in a variety of ways so that lateral forces imposed on the building will be transferred to them. For example, it is common to attach a first story shearwall to the foundation on which it sits with foundation
20 anchor bolts. The anchor bolts are embedded in the foundation and run through the bottom strut or mudsill of the shearwall and attach with a washer and nut.

When viewed in terms of resisting lateral forces, the frame is primarily an intermediate member, transmitting the lateral forces imposed on the
25 building to the shear resisting element. It does this through the fastening system. In most diaphragms, the structural panels are attached to the frame with mechanical fasteners such as nails, screws or staples, spaced around the perimeter of the structural panels according to prescribed schedules. As used in this application, these fasteners located at the perimeter of the
30 structural panel will be called perimeter fasteners to distinguish them from other fasteners located farther in from the edge faces of the structural panels. It should be noted that perimeter fasteners refer to the nails at the perimeter of the structural panels and not just the perimeter of the shear resisting element which can comprise a plurality of structural panels.

35 Nails commonly serve as the perimeter fasteners when wooden framing members are used. The perimeter fasteners are driven into the distal

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1 face of the structural panel at its perimeter, through the structural panel, and
into the framing members. Through testing, the inventors have found that
with improvements in the other elements of the typical shearwall, the
perimeter fasteners have become the critical weak link through which failure
5 of the overall system occurs.

The shear resisting element, as its name implies, works primarily in
shear. The shear resisting element can be a single structural panel, if the
diaphragm is small, or a number of structural panels, if the diaphragm is
large. Typically structural panels for use in diaphragms are made of plywood
10 or Oriented Strand Board (OSB) of structural grades, because they give a
diaphragm high shear resisting values as well as having other desirable
characteristics. Plywood and OSB come in many different grades. Typically,
structural grades such as 15/32" APA Structural 1 Rated Sheeting 32/16,
Exposure 1 are used in diaphragms to obtain sufficiently high shear values.
15 Other types of structural panels include: fiberboard, waferboard, particle
board, gypsum wall board and high density particle board. Structural panels
made from composites of different materials are also known in the art. U.S.
Patent No. 4,016,697, granted to Ericson on April 12, 1977 teaches
completely cladding one side of gypsum wall board with a thin sheet of steel
20 to improve its structural characteristics. Kevlar is also beginning to be used
with engineered wood products as ply materials.

The most basic frame consists of chords and struts located at the
perimeter of the diaphragm. In a shearwall, the top strut is commonly called
the top plate and the bottom strut is commonly called the bottom plate or
25 mudsill. The chords are commonly called end studs. The framing members
can be made of wood, engineered wood products, such as glulam, or steel,
to name a few common materials.

Most diaphragms will be made with a variety of layouts of the framing
members. If a diaphragm consists of more than one structural panel, framing
30 members need to be placed at the joint or joints of the structural panels to tie
them together, and provide support to the structural panels. If the
diaphragm serves as a load bearing structural element as well as a lateral
force resisting element, intermediate members will often be added to
strengthen the diaphragm against particular forces.

35 A shearwall, for example, is typically designed to serve as a load
bearing unit for the structures above it, as well as a lateral force resisting

1 element. Both forces work in the plane of the shearwall. In a wood frame
building, the walls are built with intermediate studs that connect the top
plate to the bottom plate to give the wall sufficient load bearing capacity.
Ordinarily, these intermediate studs are spaced 16 inches on center from
5 each other and from the end chords to give the shear wall sufficient strength.

For example, in an 8' x 8' shear wall, comprising two 4' x 8' structural
panels disposed vertically, intermediate studs spaced 16" on center will
occur both at the vertical joint of the 4' x 8' structural panels and at
intermediate points along each of the structural panels. The intermediate
10 stud at the joint between the structural panels acts as a framing member to
connect the structural panels to form a single shear resisting element. It also
provides bearing support for the top plate. The other intermediate studs
provide bearing support to the top plate. These other intermediate studs are
also attached to the structural panels.

15 Sometimes, blocking members will be added to shear walls. Blocking
members are relatively short lengths of board placed normal to and between
the intermediate studs. If the shear wall is made with a horizontal joint
between the structural panels, blocking will be added at the joint to connect
the structural panels along the entire length of the joint. For shearwall action
20 all edges of the structural panels must be supported. The blocking also
provides support to the studs against buckling under compression loads
transmitted through the top plate.

Horizontal diaphragms are also designed to serve as load bearing units,
as well as a lateral force resisting systems. Horizontal diaphragms in wood
25 frame construction serve as roofs and floor systems. Horizontal diaphragms,
in their load bearing capacity, are loaded normal to their plane. As roof and
floor systems, they are generally rather large; thus these diaphragms typically
comprise a number of structural panels. These structural panels need to be
connected at all their joints as well as the outer edges of the diaphragm. The
30 structural panels also need to be supported at intermediate points to prevent
excessive deflection under loading normal to the diaphragm. In a roof or
floor, the framing members are given various names such as: stiffeners,
rafters, joists, purlins, subpurlins, beams, headers, and girders. Blocking may
also be provided.

35 As mentioned above, the inventors tested shearwalls made according
to current building practices with the best commercially available

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1 components under cyclic loading conditions. They discovered that the
predominant failure mode is the flexing and fatiguing of the nails around the
perimeter or outer edges of the structural panels that connect the structural
panels to the frame of the diaphragm. The present invention addresses this
5 problem, allowing shearwalls and diaphragms to be both stronger and stiffer.

SUMMARY OF THE INVENTION

It is an object of the present invention to create a diaphragm that is
highly resistant to failure under cyclic loading by lateral forces.

It is a further object of this invention to improve the mechanical
10 connection between the structural panel and framing members of a
diaphragm, so that the fasteners that make the mechanical connection can
better withstand cyclic or reversing lateral forces by bending less under such
forces.

BRIEF DESCRIPTION OF THE DRAWINGS

15 **FIG. 1** is a perspective view of a vertical diaphragm or shearwall built
according to the present invention.

FIG. 2 is a perspective view of a portion of a unitary perimeter edging
member, formed as a substantially u-shaped member.

FIG. 3 is cross section of a portion of a shearwall built according to
20 the present invention taken along line 3 — 3 of **FIG. 1**, showing one of the
substantially u-shaped perimeter edging members with both of its flanges
pierced by a perimeter fastener that connects the structural panel to a
framing member.

FIG. 4 is front view of a shearwall built according to the present
25 invention. The shearwall is formed with two structural panels disposed
vertically and substantially u-shaped perimeter edging members.

FIG. 5 is an exploded, isometric view of a portion of a frame, a portion
of a structural panel and portions of substantially u-shaped perimeter edging
members, showing how they are disposed in relation to each other.

30 **FIG. 6** is a portion of a shearwall constructed according to the present
invention with substantially u-shaped perimeter edging members. The
arrows represent fasteners connecting the substantially u-shaped perimeter
edging members and the structural panel to the frame.

FIG. 7 is an isometric view of a horizontal diaphragm or floor being
35 built according to the present invention.

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1 **FIG. 8** is an isometetric view of a building structure, showing a horizontal diaphragm or roof being built according to the present invention.

FIG. 9 is an exploded, isometric view of a portion of a frame, a portion of a structural panel and portions of perimeter edging members formed as
5 elongated strips, showing how the elongated strips are disposed on both the distal side and the proximal side of the structural panel.

FIG. 10 is a portion of a shearwall constructed according to the present invention with perimeter edging members formed as elongated strips. The arrows represent fasteners connecting the perimeter edging members
10 and the structural panel to the frame.

FIG. 11 is an exploded, isometric view of a portion of a frame, a portion of a structural panel and portions of perimeter edging members formed as elongated strips, showing how the elongated strips can be disposed on the distal side of the structural panel.

15 **FIG. 12** is a portion of a shearwall constructed according to the present invention with perimeter edging members formed as elongated strips. The arrows represent fasteners connecting the perimeter edging members and the structural panel to the frame.

FIG. 13 is an exploded, isometric view of a portion of a frame, a
20 portion of a structural panel and portions of perimeter edging members formed as elongated strips, showing how the elongated strips can be disposed on the proximal side of the structural panel.

FIG. 14 is a portion of a shearwall constructed according to the present invention with perimeter edging members formed as elongated strips.
25 The arrows represent fasteners connecting the perimeter edging members and the structural panel to the frame.

FIG. 15 is an exploded, isometric view of a portion of a frame, a portion of a structural panel and portions of perimeter edging members formed as elongated strips, showing how the elongated strips can be
30 disposed within the structural panel.

FIG. 16 is a portion of a shearwall constructed according to the present invention with perimeter edging members formed as elongated strips. The arrows represent fasteners connecting the perimeter edging members and the structural panel to the frame.

35 **FIG. 17** is a portion of a shearwall constructed according to the present invention with substantially u-shaped clips.

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1 **FIG. 18** is an isometric view of substantially u-shaped clip.

FIG. 19 is side view of a portion of a shearwall constructed according to the present invention taken along line 19 — 19 of FIG. 17.

5 **FIG. 20** is a schematic of a horizontal diaphragm, showing a lateral load (w) on a diaphragm with resistance (R) being generated at the framing members parallel to the load.

FIG. 21 is a schematic of a horizontal diaphragm, showing a lateral load (w) on a diaphragm with resistance (R) being generated at the framing members parallel to the load.

10 **FIG. 22** is a graph showing deflection of the wall at each cycle, according to the procedure used in testing shearwalls made according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS OF THE INVENTION

 The present invention relates to an improved mechanical connection
15 between a structural panel 1 and the framing members 2 that support the structural panel 1 forming a diaphragm. As best shown in **FIG. 1**, the connection includes: a structural panel 1 having a distal side 3, a proximal side 4, and a plurality of edge faces 5; a frame 6 consisting of a plurality of framing members 2 disposed in registration with the proximal side 4 of the
20 structural panel 1 near the edge faces 5; a plurality of perimeter fasteners 7 connecting the structural panel 1 to the framing members 2; and means for reducing bending of the perimeter fasteners attached to substantial number of the perimeter fasteners 7. The means for reducing bending of the
25 structure 8 of which the diaphragm is a part.

 Diaphragms can take a variety of shapes. For example, **FIG. 1** shows a vertical diaphragm or shearwall 9, composed of only one structural panel 1, set on a foundation 10. The frame 6 of the shearwall 9 consists of framing members 2 disposed near the edge faces 5 of the structural panel 1 and
30 intermediate framing members 11. Means for reducing bending of the perimeter fasteners are disposed at the perimeter of the structural panel 1. Foundation bolts 12 attach the frame 6 to the foundation 10. A holdown 13 is shown attached to the frame 6. An anchor bolt 14 is shown in **FIG. 1** which attaches the holdown 13 to the foundation 10.

35 **FIG. 4** shows a vertical diaphragm or shearwall 9, composed of two structural panels 1, set on a foundation 10. The frame 6 of the shearwall 9

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1 consists of framing members 2 disposed near the edge faces 5 of the structural panels 1 and intermediate framing members 11. Means for reducing bending of the perimeter fasteners are disposed at the perimeter of both of the structural panels 1.

5 **FIG. 7** shows a horizontal diaphragm constructed as a floor 15. The frame 6 of the horizontal diaphragm consists of framing members 2. It is to be noted that because a number of different structural panels 1 will rest on a single framing member 2, and the edge faces 5 of the structural panels 1 can be offset from each other, a framing member 2 can be disposed near the
10 edge faces 5 of some of the structural panels 1 along its length and away from the edge faces 5 of other structural panels 1 along its length. A plurality of structural panels 1 are shown already attached to the frame 6. Means for reducing bending of the perimeter fasteners are disposed at the perimeter of all the structural panels 1.

15 **FIG. 8** also shows what is called a horizontal diaphragm, although it is disposed at an angle. **FIG. 8** shows the roof 16 of a building structure 8. The roof 16 is similar in composition and construction to the floor 15 of **FIG. 7**.

The means for reducing bending of the perimeter fasteners can be
20 formed in a variety of shapes; for instance, as a plurality of individual, substantially u-shaped clips 17 that work on the perimeter fasteners 7 individually, or as a single perimeter edging member 18 pierced by substantially all of the perimeter fasteners 7, or as a plurality of perimeter edging members, each of which is pierced by a plurality of perimeter
25 fasteners 7 and which together strengthen substantially all of the perimeter fasteners 7.

The species of the present invention formed as a single perimeter edging member 18, pierced by substantially all of the perimeter fasteners 7, can be shaped in a variety of ways. Furthermore, the sub-species of the
30 present invention formed as a plurality of perimeter edging members, each pierced by a plurality of perimeter fasteners 7, can be shaped in the same variety of ways. The subspecies formed as a plurality of perimeter edging members is essentially a single perimeter edging member 18 apportioned into smaller members, and as such their variations in shape are essentially
35 identical. Since this is so, the various shapes possible will only be described for the subspecies formed as a plurality of perimeter edging members. The

1 plurality of perimeter edging members can be formed as elongated strips 19
with first face members 20 pierced by the perimeter fasteners 7, or as
elongated, substantially u-shaped perimeter edging members 21.

Specifically, as shown in FIGS. 17, 18 and 19, the means for reducing
5 bending of the perimeter fasteners can consist of individual, substantially
u-shaped clips 17 having central member 22 and flanges 23 and 24
extending from the central members 23, each of said u-shaped clips 17
having its flanges 23 and 24 pierced by one of the perimeter fasteners 7.

The means for reducing bending of the perimeter fasteners can also b
10 formed as a single perimeter edging member 18 that is pierced by
substantially all of the perimeter fasteners 7. See FIG. 2. The single
perimeter edging member 18 is formed as continuous member disposed only
near the edge faces 5 of the structural panel 1 so as to be pierced by the
perimeter fasteners 7.

15 The means for reducing bending of the perimeter fasteners can also be
formed as a plurality of perimeter edging members, each being pierced by a
plurality of the perimeter fasteners 7, the perimeter edging members together
providing resistance against bending for substantially all of the perimeter
fasteners 7. These perimeter edging members can be formed as elongated
20 strips 19 with first face members 20, as shown in FIG. 12, or preferably, as
elongated, substantially u-shaped perimeter edging members 21, as shown in
FIG. 6.

Perimeter edging members formed as elongated strips 19 with first
face members 20 can be placed with the first face members 20 disposed
25 between the proximal side 4 of the structural panel 1 and the framing
members 2 near the edge faces 5 of the structural panel 1, as shown in
FIGS. 13 and 14.

Perimeter edging members formed as elongated strips 19 with first
face members 20 can also be placed with the first face members 20
30 disposed on the distal side 3 of the structural panel 1 near the edge faces 5
of the structural panel 1, as shown in FIGS. 11 and 12.

Perimeter edging members formed as elongated strips 19 with first
face members 20 can be placed with the first face members 20 disposed
within the structural panel 1 near the edge faces 5 of the structural panel 1,
35 as shown in FIGS. 15 and 16. More than one layer of perimeter edging
members formed as elongated strips 19 can be placed within the structural

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1 panel 1 at each edge face 5. Various combinations of the placement of the perimeter edging members formed as elongated strips 19 with first face members 20 can be used, according to the builder's preferences.

As shown in FIGS. 1 and 3, in the preferred embodiment, the
5 perimeter edging members are formed as elongated, substantially u-shaped perimeter edging members 21, having central members 25 that have first and second flanges 26 and 27 extending from the central members 25. Both of the flanges 26 and 27 are pierced by each perimeter fastener 7 receiving the benefit of the means for reducing bending of the perimeter fasteners.

10 The first and second flanges 26 and 27 of the substantially u-shaped perimeter edging members can be disposed in relation to the structural panel 1 in a variety of ways, depending on the builder's preferences.

The first flanges 26 of the substantially u-shaped perimeter edging members 21 can be disposed between the framing members 2 and the
15 proximal side 4 of the structural panel 1, while the second flanges 27 are disposed on the distal side 3 of the structural panel 1 near the edge faces 5. See FIGS. 5 and 6.

Alternatively, the first flanges 26 of the substantially u-shaped perimeter edging members 21 can be disposed within the structural panel 1
20 near the edge faces 5, and the second flanges 27 of the u-shaped perimeter edging members 21 can be disposed on the distal side 3 of the structural panel 1 near the edge faces 5.

The first flanges 26 of the substantially u-shaped perimeter edging members 21 can also be disposed between the framing members 2 and the
25 proximal side 4 of the structural panel 1, and the second flanges 27 can be disposed within the structural panel 1.

Further, the first flanges 26 of the substantially u-shaped perimeter edging members 21 can be disposed within the structural panel 1 near the edge faces 5, and the second flanges 27 can also be disposed within the
30 structural panel 1 near the edge faces 5.

As mentioned earlier, in the preferred embodiment, the means for reducing bending of perimeter fasteners is formed as a plurality of substantially u-shaped perimeter edging members 21, pierced by a plurality of perimeter fasteners 7. Substantially u-shaped perimeter edging members
35 21 reduce nail bending well while being easier to install than the other embodiments. By being easier to install, the preferred embodiment better

1 ensures that all diaphragms constructed with means for reducing bending of the perimeter fasteners are uniform in the shear resisting load values they achieve.

5 The dimensions of the preferred substantially u-shaped perimeter edging members 21 depend on the dimensions of the structural panel 1. When used with a 15/32" thick structural panel 1, the preferred embodiment is formed with 1/2" central members 25 and 1" first and second flanges 26 and 27 extending from the central members 25.

10 The means for reducing bending of the perimeter fasteners can be made of any material that has a higher bearing strength than the structural panel 1 with which it is used. When the structural panels 1 are plywood or OSB, materials such as aluminum, steel and certain plastics could be used. In the preferred embodiment, where the structural panel is OSB, the means for reducing bending of the perimeter fasteners is formed from 20 gauge
15 galvanized sheet metal.

The means for reducing bending of the perimeter fasteners can be bonded, mechanically attached, incorporated into the structural panels 1 or attached during assembly of the diaphragm. The preferred method is to attach the means for reducing bending of the perimeter fasteners during
20 assembly to accommodate diaphragms of all shapes and sizes. If the diaphragm is large and will be built with a number of structural panels 1 of equal size, it may be preferable to incorporate the means for reducing bending of the perimeter fasteners into the structural panels 1 as they are created. For example, a kerf cut could be made that runs the length of each
25 of the edge faces 5 of the structural panel 1, and then the first flanges 26 of the substantially u-shaped perimeter edging members 21 could be inserted into the kerf cuts, achieving a friction fit.

Openings can be formed in the means for reducing bending of the perimeter fasteners to facilitate hand installation of the perimeter fasteners 7;
30 however, the preferred method is to, at least initially, drive the perimeter fastener 7 with a power tool, in which case no openings are necessary.

The perimeter edging members are preferably made in 4' lengths. Structural panels 1 are typically sold as 4' x 8' panels, and a 4' long perimeter edging member integrates easily with these dimensions and is also
35 easy to handle. See FIGS. 1 and 4.

1 In a larger diaphragm consisting of multiple structural panels,
perimeter edging members formed as elongated strips 19 with first face
members 20 can be used that are approximately 2" wide and 4' long at the
joints of the structural panels 1. The 2" wide elongated strips 19 are used
5 on both of the structural panels 1 that meet at the joint. Specifically, the
elongated strips 19 overlap both structural panels 1 on either side of the
joint. They are attached as if two elongated strips 19 that were 1" wide
were used. Using such elongated strips 19 not only reduces the bending of
the perimeter fasteners 7 for each structural panel 1 on either side of the
10 joint, they also improve the connection between the structural panels 1 so
that they act in a more unified manner.

The preferred perimeter fasteners 7 for attaching the structural panel 1
to the framing members 2 are 10d x 3" long common nails. In a shearwall 9
with wood framing members 2, the perimeter fasteners 7 should be spaced
15 around the perimeter of the structural panel 1 at 2" on center to provide the
highest shear value for the shearwall 9. Less closely spaced perimeter
fasteners 7 provide lower shear resistance values for the diaphragm, while
more closely spaced perimeter fasteners 7 can lead to splitting of the framing
members 2 when wooden framing members 2 are used. Perimeter fasteners
20 7 should be spaced at least 3/8 inches from the edge faces 5 of the
structural panel 1.

The structural panels 1 are also field-nailed to any portions of the
frame 6 not located at the perimeter of the structural panels 1, usually at 6
to 12 inches on center. Where larger diaphragms are built that consist of
25 more than one structural panel 1, nailing schedules may differ along the
perimeter of the structural panels 1 according to where the structural panels
1 are placed in the diaphragm.

The structural panels 1 are preferably made from Oriented Strand
Board 15/32" APA Structural 1 Rated Sheeting 32/16, Exposure 1. Higher
30 diaphragm shears can be carried with increased structural panel 1 thickness,
however, increased thickness adds cost to the materials. Structural panels 1
with the above specifications are generally sufficiently strong without being
too costly.

In a 4' wide by 8' tall shearwall 9 constructed from a single 4' x 8'
35 structural panel 1 disposed vertically, with wooden framing members 2, and
resting on a foundation 10, the chords or framing members disposed at the

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- 1 vertical edge faces of the structural panel 1 are preferably made of kiln-dried
Southern Yellow Pine (MSR) 4x4s. The bottom strut that rests on the
foundation 10 should be a pressure treated 2 x 4. The top strut or the
framing member near the top edge of the structural panel 1 is preferably
5 formed as two kiln-dried Southern Yellow Pine (MSR) 2x4s joined together.

Testing of the Present Invention

In order to characterize the improvements associated with the present
invention, shearwalls were constructed in accordance with the present
invention and compared to shearwalls constructed in accordance with current
10 practices that did not make use of the present invention.

The shearwalls were tested in Brea, California at the Simpson
Strong-Tie Co. Laboratory on a machine designed to simulate the cyclic
(reversing) lateral forces that would be imposed on a shearwall or vertical
lateral force resisting system during an earthquake.

- 15 The test can be used to measure the strength of the shearwall and
the stiffness of the shearwall. Stiffness of a shearwall is measured in terms
of the force that is required to displace the top of the wall a given distance.
The strength of a shearwall can be described in these same terms as well as
by how much force is required to cause a failure of the shearwall, that is the
20 point when the shearwall no longer provides any meaningful resistance to
lateral forces. Test results are reported in tables 1 and 2 for a number of
different shearwalls in terms of the force required to displace the top of the
wall 0.5" under cyclic loading conditions (Load at 0.5") and the load at
which failure of the wall occurs (Maximum Load). The test show that
25 shearwalls constructed with means for reducing bending of the perimeter
fasteners are both stronger and stiffer than shearwalls that did not have
them.

The tests were conducted according to a protocol developed by the
Joint Technical Coordinating Committee on Masonry Research (TCCMAR) in
30 1987. See Porter, M.L., Sequential Phased Displacement (SPD) procedure
for TCCMAR Testing, Proceedings of the Third Meeting of the Joint
Technical Coordinating Committee on Masonry Research, US - Japan
Coordinated Earthquake Research Program, Tomamu, Japan.

- The TCCMAR procedure hinges on the concept of the First Major
35 Event (FME), which is defined as the first significant limit state which occurs
during the test. The FME occurs when the load capacity of the wall, upon

1 recycling of load to the same wall displacement increment, first drops
noticeably from the original load and displacement. FME for all tests was
assumed to occur when an 8 foot high shearwall can be displaced 0.8 inches
at its top.

5 The TCCMAR procedure consists of applying cycles of fully-reversing
displacement to the shearwall at various increments of the wall's assumed
FME. See FIG. 22.

In the first phase, three cycles of fully-reversing displacement are
applied to the top of the shearwall at 25% of FME. The first phase continues
10 by then applying three cycles of fully-reversing displacement at 50% of FME.
Then, three cycles of fully-reversing displacement are applied at 75% of
FME. Then, the fully-reversing displacement is increased for one cycle to
100% of FME. This is the maximum displacement for this first phase. Next,
"decay" cycles of displacement for one cycle each at 75%, 50%, and 25%
15 of the phase-maximum are applied in that order respectively. Then, three
stabilizing cycles of displacement at the phase-maximum (100% of FME) are
applied to the top of the shearwall. These phase-ending cycles stabilize the
load-displacement response of the shearwall, prior to the next phase of
testing.

20 In the second phase, which follows immediately according to the test
frequency, one phase-maximum cycle of fully-reversing displacement is
applied at 125% of FME. Next, "decay" cycles of displacement for one
cycle each at 75%, 50%, and 25% of the maximum for that phase are
applied in that order respectively. Then, three stabilizing cycles of
25 displacement equal to the phase-maximum cycle (125% of FME for the
second phase) are applied to the shearwall.

In the third phase, one phase-maximum cycle of fully-reversing
displacement at 150% of FME is applied to the shearwall. Next, "decay"
cycles of displacement for one cycle each at 75%, 50% and 25% of the
30 phase-maximum cycle are applied. Then, three stabilizing cycles of
displacement equal to the phase-maximum of the cycle (150% of FME for
the third phase) are applied to the top of the shearwall.

Successive phases are continued in a like manner as the second and
third phases at increased increments, as shown in FIG. 22. The incremental
35 cyclic load-displacement phases are continued at phase-maximums of 175%,
200%, 250%, 300%, 350% and 400% of FME, or until the wall exhibits

1 excessive displacement, or until the wall displacement exceeds the capacity
of the test equipment, which in this case was ± 3.0 inches. In all trials, the
lateral load capacity of the shearwall had greatly diminished by the time the
shearwall was displaced 3.0 inches.

5 Racking shear loads were applied to the test specimens through an
actuator located at the top of the wall. The actuator was placed so that the
actuator did not interfere with any movement of the structural panels. The
actuator that caused deflection at the top of the shearwall was computer
controlled. Actuator loads were applied to the wall at a frequency of one
10 cycle per second.

The shearwall test specimens were attached to the base of the test
frame with 5/8 inch diameter anchor bolts, passing through the framing
member sitting on the test frame, spaced approximately 12 inches on center,
and approximately 12 inches from the ends of the shearwall.

15 The vertically disposed framing members, or chords, of the shearwall
test specimens were attached to the test frame with holdowns and 7/8" inch
anchor bolts that passed through the framing member that sat on the test
frame or bottom strut. All tests were conducted with Simpson Strong-Tie
PHD8 holdowns, except tests D596, F568 and F570. The shearwall of test
20 D596 was built according to common construction practices and so used
Simpson Strong-Tie HD8A holdowns. Test F568 used a modified Simpson
Strong-Tie PHD8 in combination with means for reducing perimeter fastener
bending to achieve even higher load values. Test F570 also used modified
Simpson Strong-Tie PHD8 holdowns. This is noted in the table as
25 "PHD8 + 8". The holdowns were attached to the inner faces of the vertically
disposed framing members. The holdowns were attached to the vertically
disposed framing members with 1/4" diameter by 3" long Simpson Strong
Drive screws in the case of the PHD8 and PHD8 + 8 holdowns, and with
three 7/8" diameter bolts in the case of the HD8A holdown. Anchor bolts
30 attached the holdowns to the test frame. FIGS. 1 and 4 show typical
shearwalls attached to their foundation.

Lumber used for framing in all tests was Green Douglas Fir, except for
the bottom strut or framing member which sat on the test frame which was
pressure treated Hem-Fir. At the time of the test, the lumber moisture
35 content was approximately 20 to 25 percent.

1 The top strut or framing member at the top of the structural panel
consisted of doubled 2 x 4s connected with 16d box nails. The top struts
for each shear wall were 48" long. The framing members that sat on the
test frame were also 2 x 4s. In addition to the above mentions framing
5 members two intermediate 91 and 1/2 inches long 2x4 studs, spaced 16" on
center from each other and the chords, were added and end-nailed to the
horizontally disposed framing members with nails according to currently
accepted building practices.

4x4s were used for the chords or vertically disposed framing
10 members. In all tests, except test D596 which reflects current building
practices, the vertically dispose framing members, or chords, were 93 inches
tall. This means the chords sat directly on the test frame. Setting the
chords on the test frame eliminates failure of the shearwall due to crushing
of the bottom strut by the chords, and greatly improves its performance.
15 This particular design of using long chords that bypass the bottom strut is
particularly effective where the shearwall sits on the relatively
non-compressible building foundation. This is demonstrated by comparing
test D596 to F494. Test D596 used a 91 1/2 inches tall 4x4 chord that sat
on the bottom strut. The bottom strut or bottom plate in this test was
20 longer to allow the chords to sit on the bottom strut.

Plywood and Oriented Strand Board structural panels were used for
the structural panel or shear resisting element in the tests. For most of the
tests 15/32" APA Structural 1 Rated Sheeting 32 /16, Exposure 1 was used.
For tests F564 and F568 Oriented Strand Board with the following
25 specifications was used: 15/32" APA Structural 1 Rated Sheeting 32 /16,
Exposure 1.

All tests were conducted with one 4' x 8' structural panel sheathing
applied to the framing members with the face grain or strength axis disposed
vertically.

30 The structural panels were fastened to the framing members by steel
10d common nails that were either 2.125" long or 3" long. All nails were
driven into the framing members to a depth of at least 11 times their shank
diameter to comply with the Uniform Building Code. All nails were driven so
that the head of the nail sat flush against the distal side of the structural
35 panel. When means for reducing the bending of the mechanical fasteners
were used, the nails were first power-driven to start and then hand-driven to

1 finish the attachment. All nails were spaced 2 inches on center around the periphery of the structural panel. The structural panel was attached to the intermediate studs with 10d x 3" long common nails spaced 12 inches on center.

5 Test D568, which achieved the highest load values, used a special holdown not used in any other tests. The holdown was a modified Simpson Strong-Tie PHD8. The back of the holdown was extended to allow 8 more screws to be used to attach the holdown to the chord. Test F570 also used a modified Simpson Strong-Tie PHD8 holdown. The difference in the
10 holdown is indicated in table 1 and table 2 as "PHD8 + 8".

All means for reducing bending of perimeter fasteners were formed from 20 gauge galvanized sheet metal.

Test D596 represents a shearwall built according to current practices. No means for reducing bending of the perimeter fasteners were used. It
15 serves as control for the other tests.

Test F495 also serves as a control for the other tests as it does not have means for reducing bending of the perimeter fasteners. The improved performance of test F495 is believed to be due to the fact that improved holdowns were used, and the chords or first and second framing members
20 bypassed the bottom strut and sat directly on the test frame avoiding end crushing of the bottom strut.

In tests F522 and F494 substantially u-shaped perimeter edging members were added to shearwalls using improved holdowns and having chords that bypassed the bottom strut. The first flanges of the u-shaped
25 perimeter edging members were disposed between the framing members and the proximal side of the structural panel and the second flanges were disposed on the distal side of the structural panels.

In test F551, perimeter edging members formed as elongated strips with first face members were used. A first set of perimeter edging member
30 was placed between the framing members and the proximal side of the structural panel. A second set of perimeter edging members was placed on the distal side of the structural panel near the edge faces such that each perimeter fastener passed through two perimeter edging members.

In tests F564 and F568, substantially u-shaped perimeter edging
35 members were used as in tests F522 and F494, however, the structural

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1 panel in both tests was made out of Oriented Strand Board rather than plywood. Test F568 also used a further improved holdown.

5 In test F538, perimeter edging members formed as elongated strips with face members were used as in test F551, however the perimeter edging members were only disposed between the framing members and the proximal side of the structural panel.

In test F537, the perimeter edging members formed as elongated strips with face members were disposed only on the distal side of the structural panel.

10 In test F570, the means for reducing bending of the perimeter fasteners consisted of individual, substantially u-shaped clips attached to the perimeter fasteners. The flanges of the u-shaped clips were disposed on the distal and proximal sides of the structural panel. Test F570 also used a further improved holdown.

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1 Table 1

TEST:	D596	F495	F522	F494	F551	F564	F568
DATE:	5/15/95	2/5/97	2/24/97	4/10/97	3/17/97	4/1/97	4/3/97
nails:	10d X 3"	10d X 2.125"	10d X 3"	10d X 2.125"	10d X 3"	10d X 3"	10d X 3"
schedule:	2" OC	2" OC	2" OC	2" OC	2" OC	2" OC	2" OC
panel:	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" OSB	15/32" OSB
chord design:	short stud	long stud	long stud	long stud	long stud	long stud	long stud
means for reducing bending...:	none	none	"u"	"u"	strip on each side	"u"	"u"
holdown:	HD8A	PHD8	PHD8	PHD8	PHD8	PHD8	PHD8+8
Load at 0.50":	1,950 lbs.	4,400 lbs.	4,650 lbs.	5,250 lbs.	4,950 lbs.	4,850 lbs.	6,200 lbs.
Maximum Load:	6,200 lbs.	8,250 lbs.	11,800 lbs.	11,850 lbs.	12,050 lbs.	12,150 lbs.	13,000 lbs.

Table 2

TEST:	D596	F495	F538	F537	F570	F568
DATE:	5/15/95	2/5/97	3/7/97	3/7/97	4/10/97	4/3/97
nails:	10d X 3"	10d X 2.125"	10d X 3"	10d X 3"	10d X 3"	10d X 3"
schedule:	2" OC	2" OC	2" OC	2" OC	2" OC	2" OC
panel:	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" structural 1 plywood	15/32" OSB
chord design:	short stud	long stud	long stud	long stud	long stud	long stud
means for reducing bending...:	none	none	strip inside	strip outside	clips	"u"
holdown:	HD8A	PHD8	PHD8	PHD8	PHD8+8	PHD8+8
Load at 0.50":	1,950 lbs.	4,400 lbs.	4,550 lbs.	4,850 lbs.	4,600 lbs.	6,200 lbs.
Maximum Load:	6,200 lbs.	8,250 lbs.	10,450 lbs.	10,550 lbs.	11,000 lbs.	13,000 lbs.

The invention is not limited to the specific form shown, but includes all forms within the definitions of the following claims.